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## Glass investment casting with 3D printed moulds


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# Ceramic Shell investment casting technique

# INVESTMENT CASTING

FORTUS
3D PRODUCTION SYSTEMS

Time Required ■■□ Cost ■■□ Skill Level ■■□

By Rob Winker, Stratasys, Inc.

## OVERVIEW

Investment casting, also called lost wax casting, is widely used for producing ferrous and non-ferrous metal parts. Unlike other casting processes, investment casting produces net shape parts with excellent surface finish and dimensional accuracy. This manufacturing process is ideal for applications that have relatively low production quantities (10 to 10,000 pieces) or rapidly changing product designs.

Nearly 200 alloys are available with investment casting. These metals range from ferrous—stainless steel, tool steel, carbon steel and ductile iron—to non-ferrous—aluminum, copper and brass. When cast in vacuum, super alloys are also available. The only process that matches this breadth of materials is machining, but it cannot produce the complex geometries that investment casting can deliver.

Since investment casting uses expendable patterns and ceramic shells, it is excellent for complex and detailed part designs. The process manufactures intricate parts that are difficult, if not impossible, to machine, forge or cast. Examples include internal passages and ports in a valve body, curved vanes of an impeller and internal cooling channels in a turbine blade.

The critical barrier in prototype development and short-run production is the time and cost for injection molds. Each metal casting requires one wax pattern, and these patterns are injection molded. As design complexity rises, the tooling often becomes too costly and too time consuming to make prototyping and low-volume production practical.

## FDM AND INVESTMENT CASTING

The key advantage of FDM (fused deposition modeling) is that it eliminates the need for tooling. Injection molds for wax patterns range from $3,000 to $30,000, and building the tools can take four to six weeks. With FDM, the tooling cost is eliminated and the lead time for a cast part is slashed to just 10 days on average. This yields a savings of $30,000 and two to four weeks for a typical project, which makes investment casting viable for prototype quantities (figure 1).

The time and cost savings are true no matter how complex the part's design. Since FDM is an additive fabrication technology, there is no impact on the investment or delivery schedule as the pattern becomes more complex. Another advantage, which is unique to FDM, is that the soluble support technology allows interior passages to be constructed. Additional time savings also occur in casting design, since FDM patterns can be produced without adding draft angles to the CAD data.

A final consideration is the durability of the pattern. Patterns made from foundry wax and other additive fabrication technologies are easily damaged. And, transportation and routine handling can result in broken patterns. The strength and toughness of an ABS part built on a Fortus 3D Production System virtually eliminates pattern damage and the delays it can cause. The ABS material is also resistant to distortion from heat, humidity and post curing which can be an issue with other additive fabrication technologies.

## PROCESS OVERVIEW

The investment casting process begins with a pattern. Traditionally, the pattern was injection molded in foundry wax, but this is replaced by ABS patterns made on a Fortus system.

Gates and vents are attached to the pattern, which is then attached to the sprue. After all patterns are mounted to the sprue producing what is called a casting tree. At this point the

*APPLIES TO MATERIALS:*
*- ABS, ABSplus, ABS-M30, ABS-M30i*

*SUPPLIES:*
*- Solvent*
*- Typical investment casting supplies*

Figure 1: *Investment casting (left) made from FDM pattern (right) eliminates tooling for molding of wax patterns.*

Casting Design:
- *Fillets: 0.030 inch min. radius*
- *Edges: Sharp to 0.020 inch min.*

Casting Deliverables:
- *Angles: +/- 1.0 degree*
- *Tolerance: +/- 0.005 inch*
- *Surface finish: 60 - 125 _in RMS*
- *Flatness: +/- 0.005 inch/inch*
- *Size: < 1 oz to 20 lb.*
- *Quantity: 1 to 5,000 typical*





Stratasys finishing station, which will remove layer lines and seal the surfaces of the pattern. If the Stratasys finishing station is not available, dipping or brushing the part in or with a solvent like Weld-On #3 or acetone will provide similar and suitable results.

If desired, the pattern can then be sanded to improve the surface finish. Alternatively, paste wax and acrylic paints may be used. However, before using either material, contact the foundry to make sure that it is compatible with its casting process.

## PATTERN ASSEMBLY

If the pattern size exceeds the build envelope of the Fortus system, it can be split into multiple pieces and assembled. To join the pieces, Ambroid® PROWELD, a product that chemically bonds ABS plastic, is available from and recommended by Stratasys. Other bonding material may be used, but as with the finishing materials, contact the foundry to determine what materials are suitable.

## CASTING TREE ASSEMBLY

If gates were not built as part of the FDM pattern, they are added at this time. Made from foundry wax, the gates are wax welded to the pattern. In addition to gates, wax vents should be attached to the FDM patterns. During the burnout process, the patterns will combust and release some gas. The vents allow the gas to escape during burnout and promote air flow for combustion.

To allow this airflow, drill holes into the FDM pattern exposing the sparse interior. These holes will be covered with the wax from the gates and vents. If the gates or vents were built into the model drill out the ends exposing the sparse interior, this will be covered by the wax when it attached to the sprue.

Next, the gated patterns are attached to the wax sprue, also with wax welding. When all patterns are attached, the casting tree is ready for shelling.

## SHELLING

A ceramic shell, approximately 0.375 inches (9.53 mm) thick, is created around the casting tree. The result is the investment into which the alloy is cast.

The casting tree is dipped in a face coat of agitated ceramic slurry and then coated with a stucco of fine sand (figure 4). The face coat process is repeated and followed by four more coats of slurry. The shell is then dried under controlled conditions.

When using FDM patterns, additional layers of ceramic slurry should be applied to minimize shell cracking during the burnout process. For example, if a traditional casting tree made from wax patterns is shelled with seven layers of slurry, the casting tree made from FDM patterns should get 10 layers of slurry (figure 5).

After the shelling process is completed, cut the ceramic off of the vents exposing the wax or ABS vent. This process is critical in getting a complete burnout without cracking the ceramic shell.

## BURNOUT

The critical modification to standard foundry procedures is in the burnout of the pattern from the ceramic shell. The standard processes of removing the casting tree by melting the wax in a steam autoclaving is not suitable for evacuation of the FDM pattern. Instead, a higher temperature, longer duration furnace cycle is required to burn out the FDM pattern.

Burnout procedure proven successful when using ABS patterns.

**Step 1:** Use the standard autoclave procedure to melt out the wax vents, gates, and sprue.

**Step 2:** Completely dry the shell by placing it in a warm, well ventilated location.

**Step 3:** Burn out the ABS pattern by placing it in a flash furnace and ramping the temperature up to 1600 F (870 C) – 1950 F (1066 C) for one to four hours. (Note: Work with the Investment Casting facility to determine the correct time and temperatures needed.)

Following the furnace cycle, inspect the shells to determine if burnout is complete. If needed, return the shell to the furnace and continue the burnout.

## SHELL WASHING

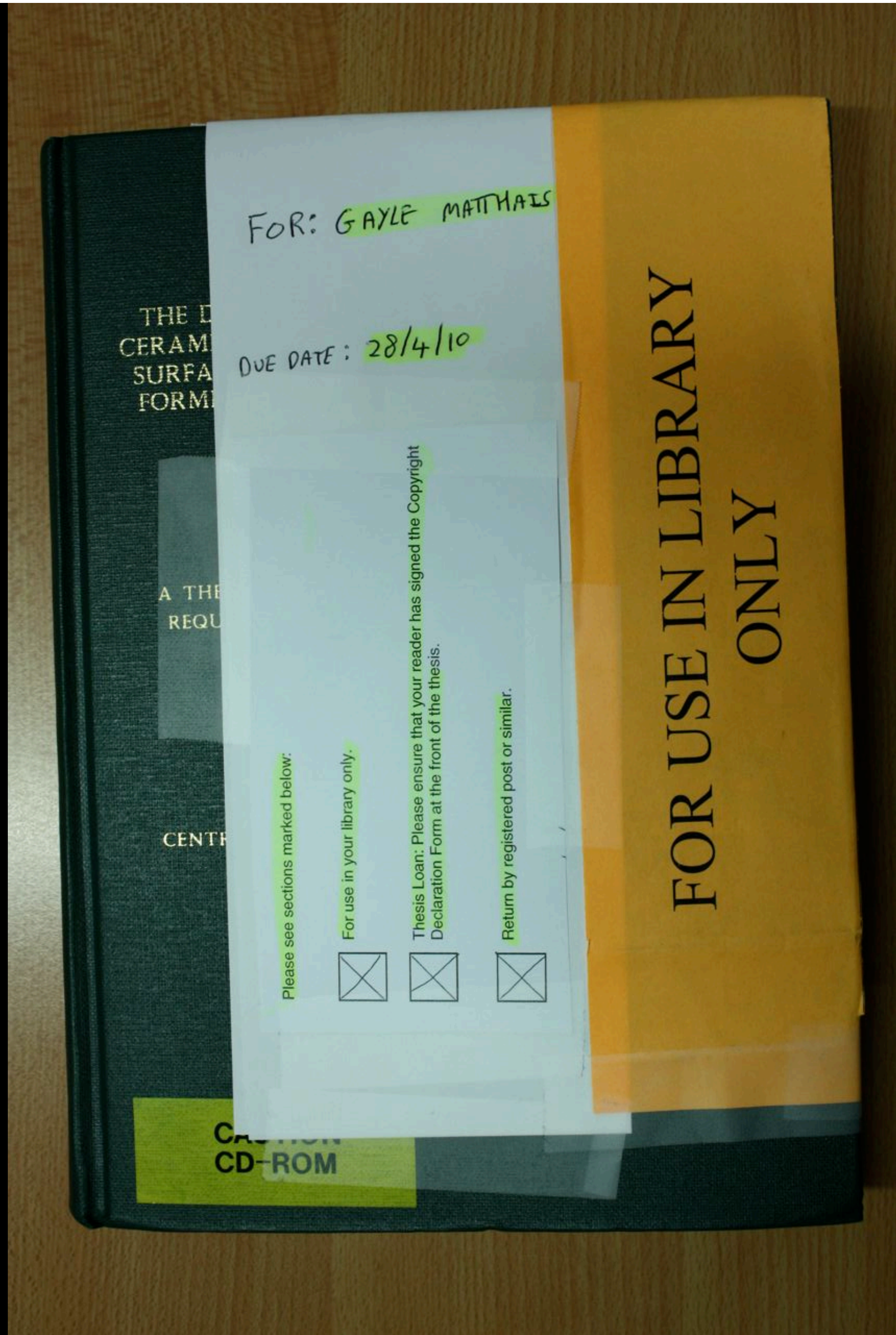
To remove ash and ceramic dust, the shell is washed with a forceful stream of water. If using fused silica for the shell, it may be washed immediately after removal from the furnace. The water stream is allowed to enter one gate and exit through another gate or a vent. During washing,

Figure 3: *FDM pump body pattern, made from ABS-M30, is ready for shelling after sealing and sanding.*

Figure 4: *Shelling tree being dipped into ceramic slurry.*

Figure 5: *Parts on casting tree after shelling process.*




Gayle Matthias

Fused Deposition Modeling (FDM) Rapid Prototyping

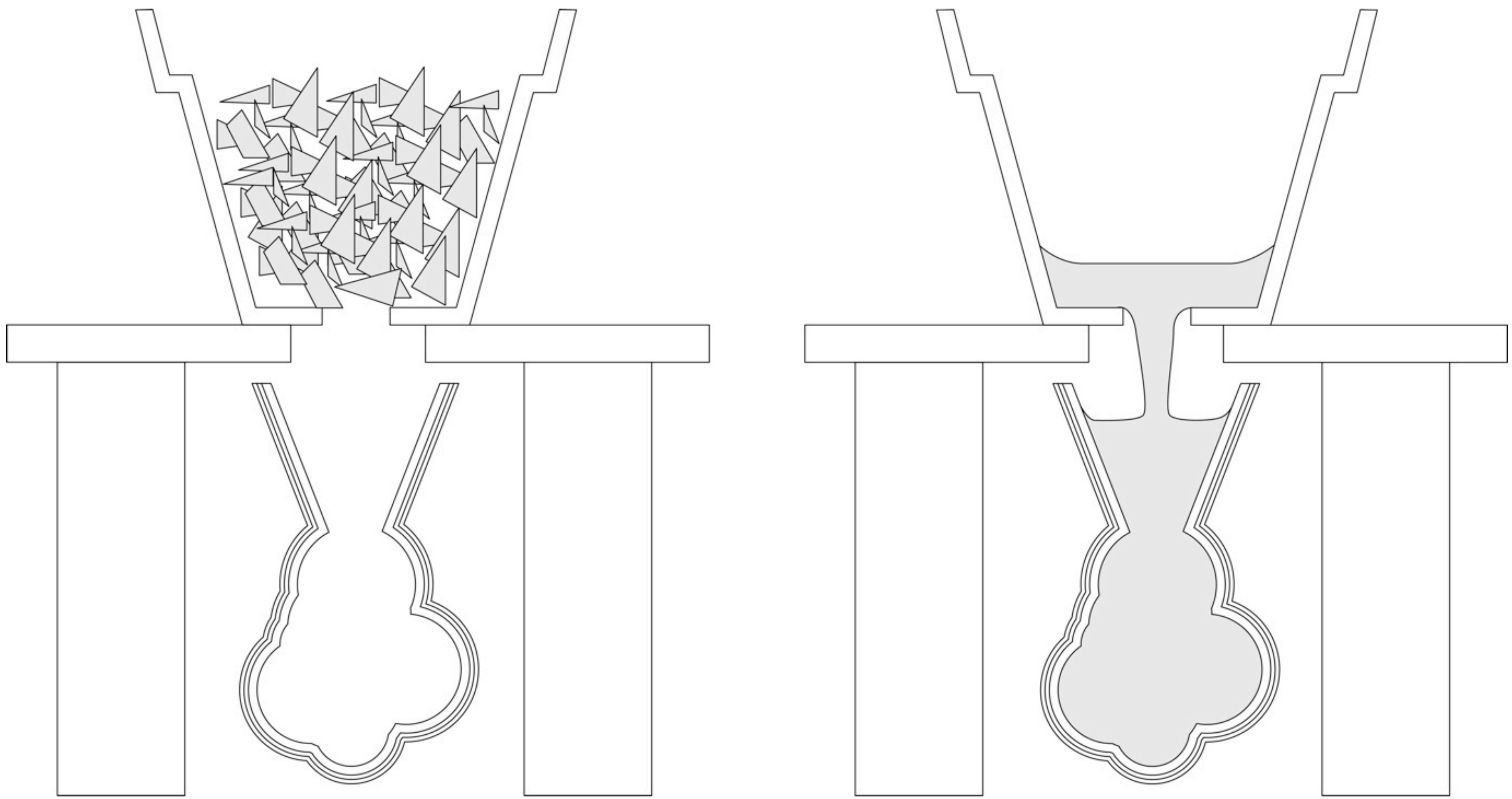

Mixing Area



ZCorporation RP starch models



Glass casting with flowerpot funnel / reservoir



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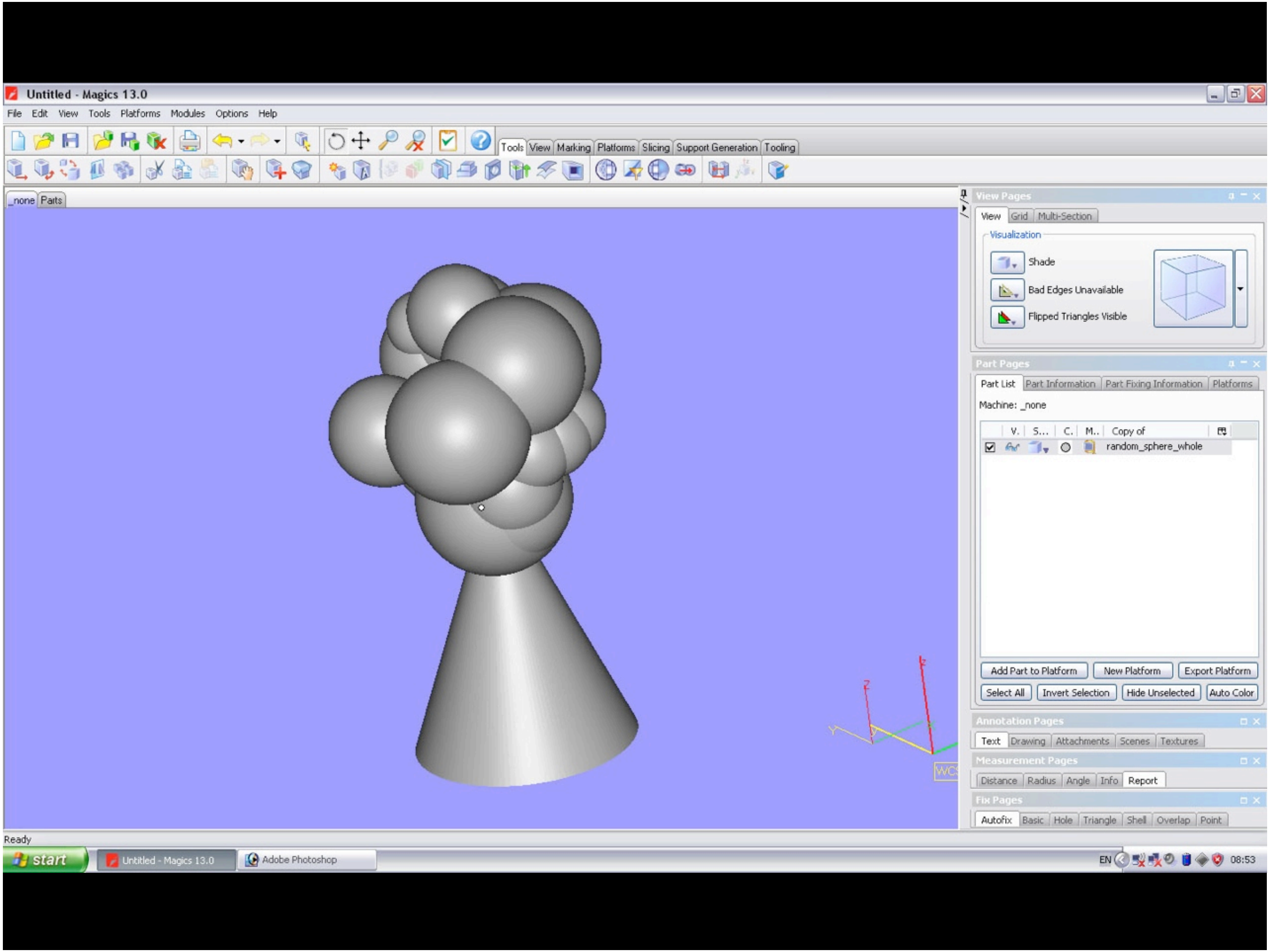
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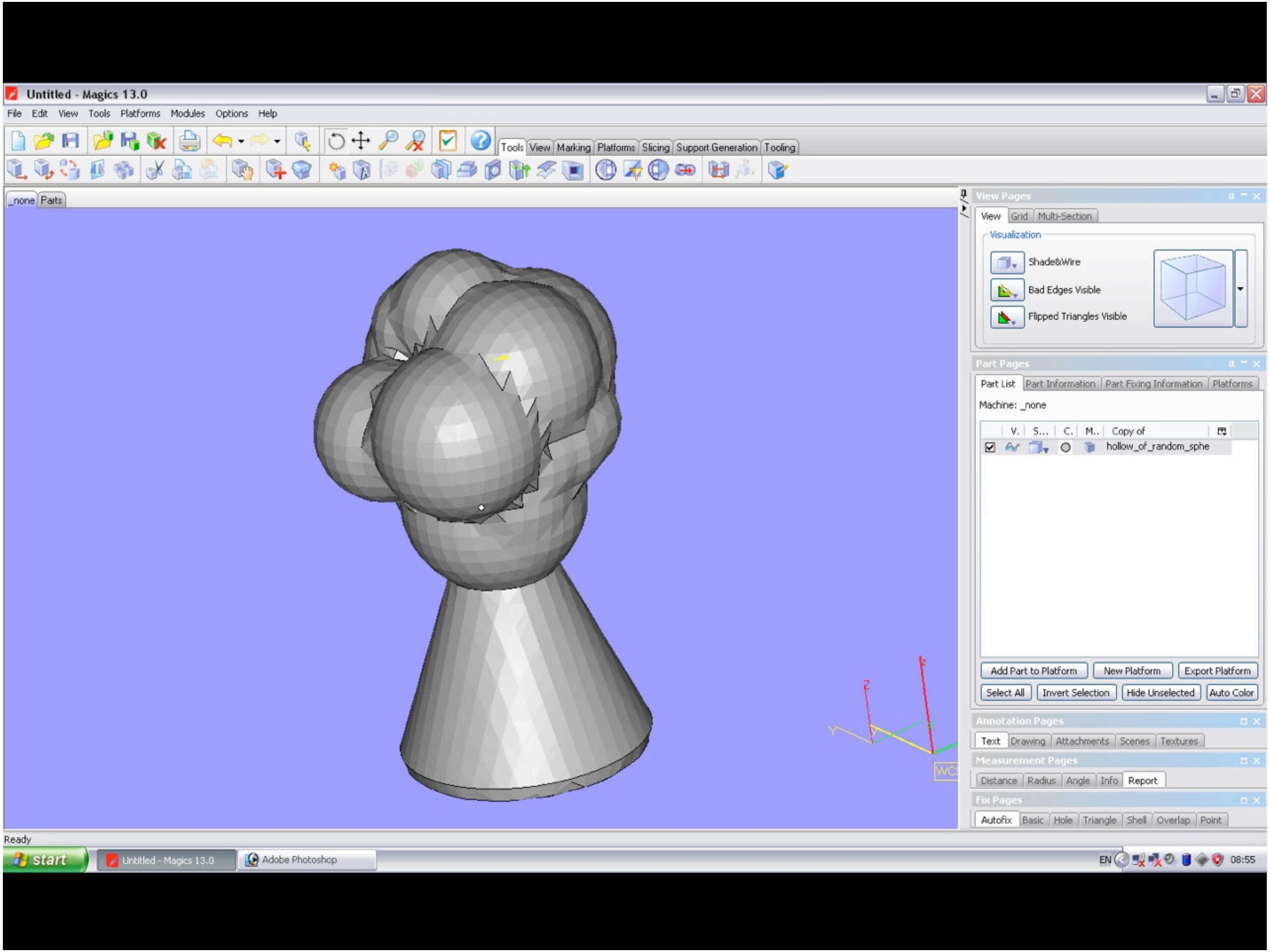
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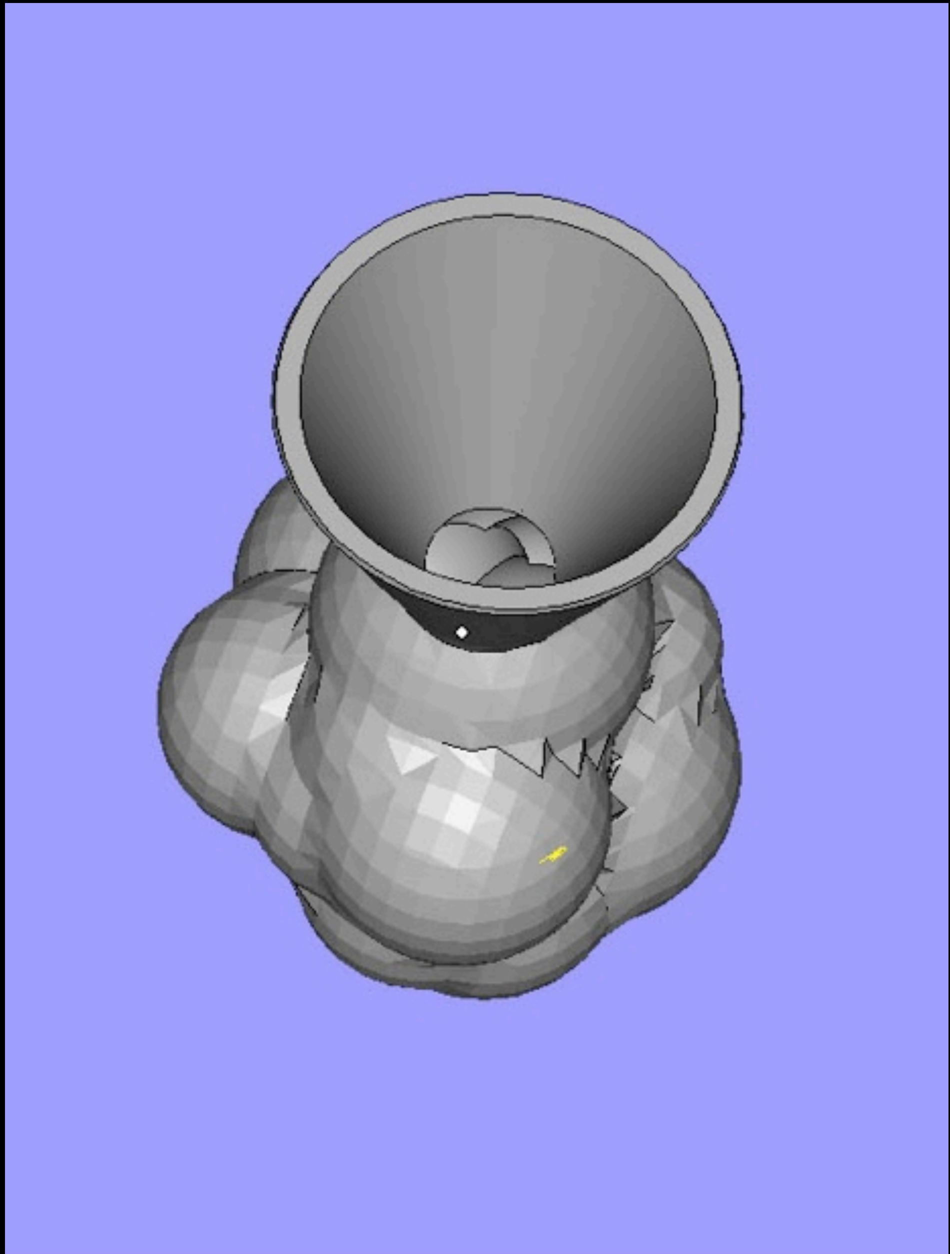
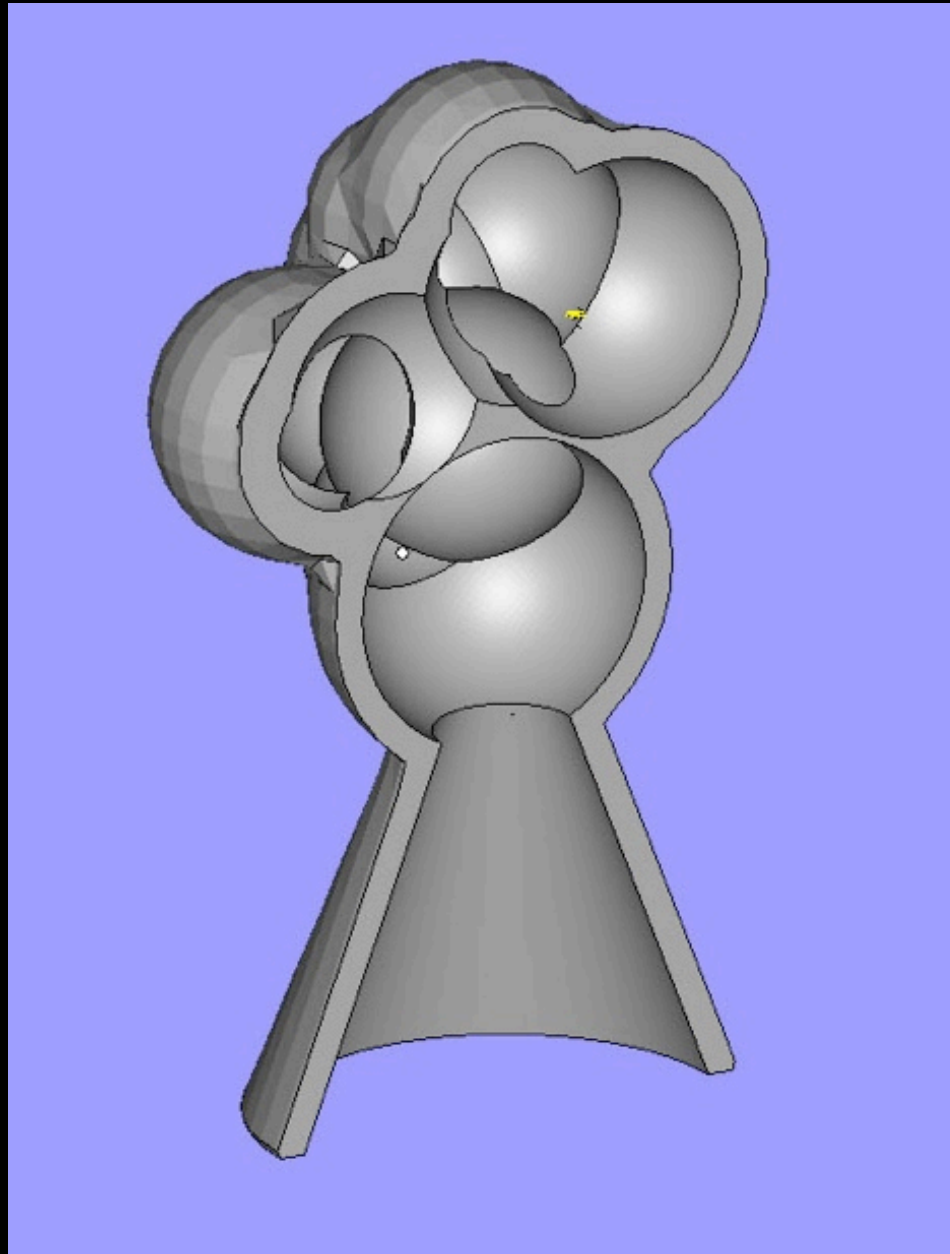
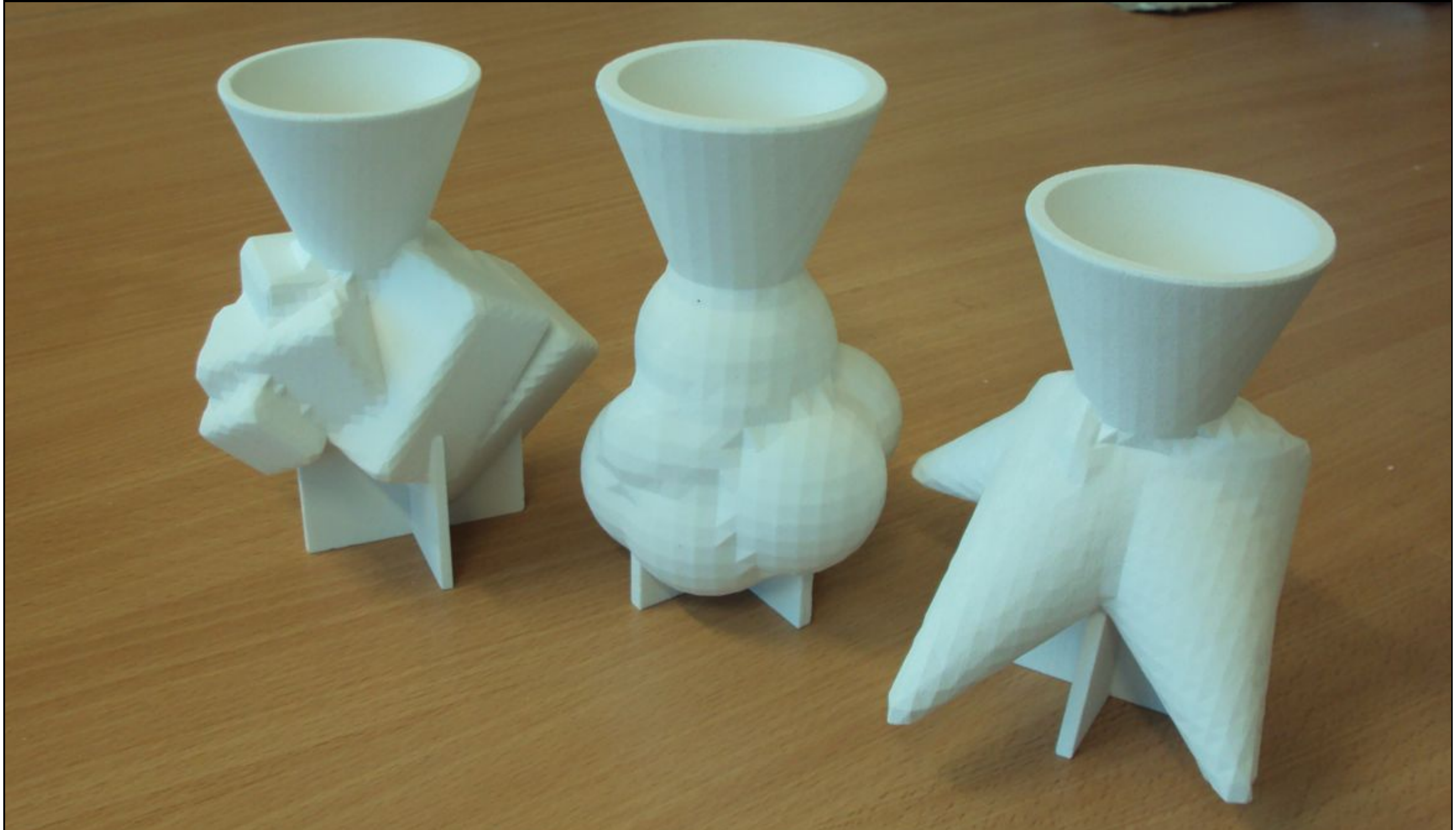




Rapid Tooling



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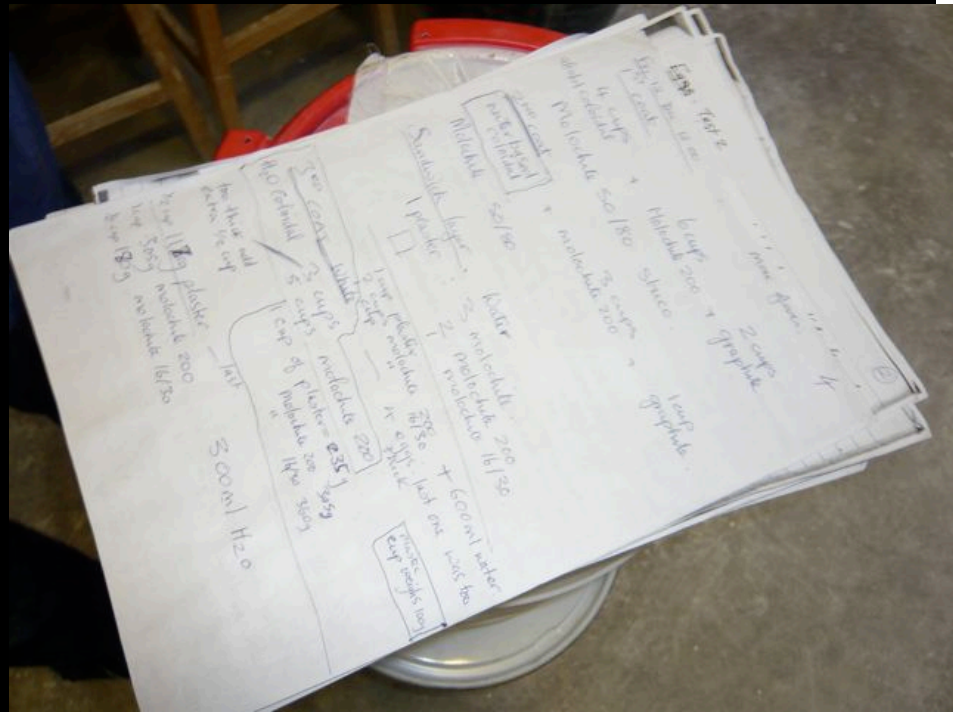


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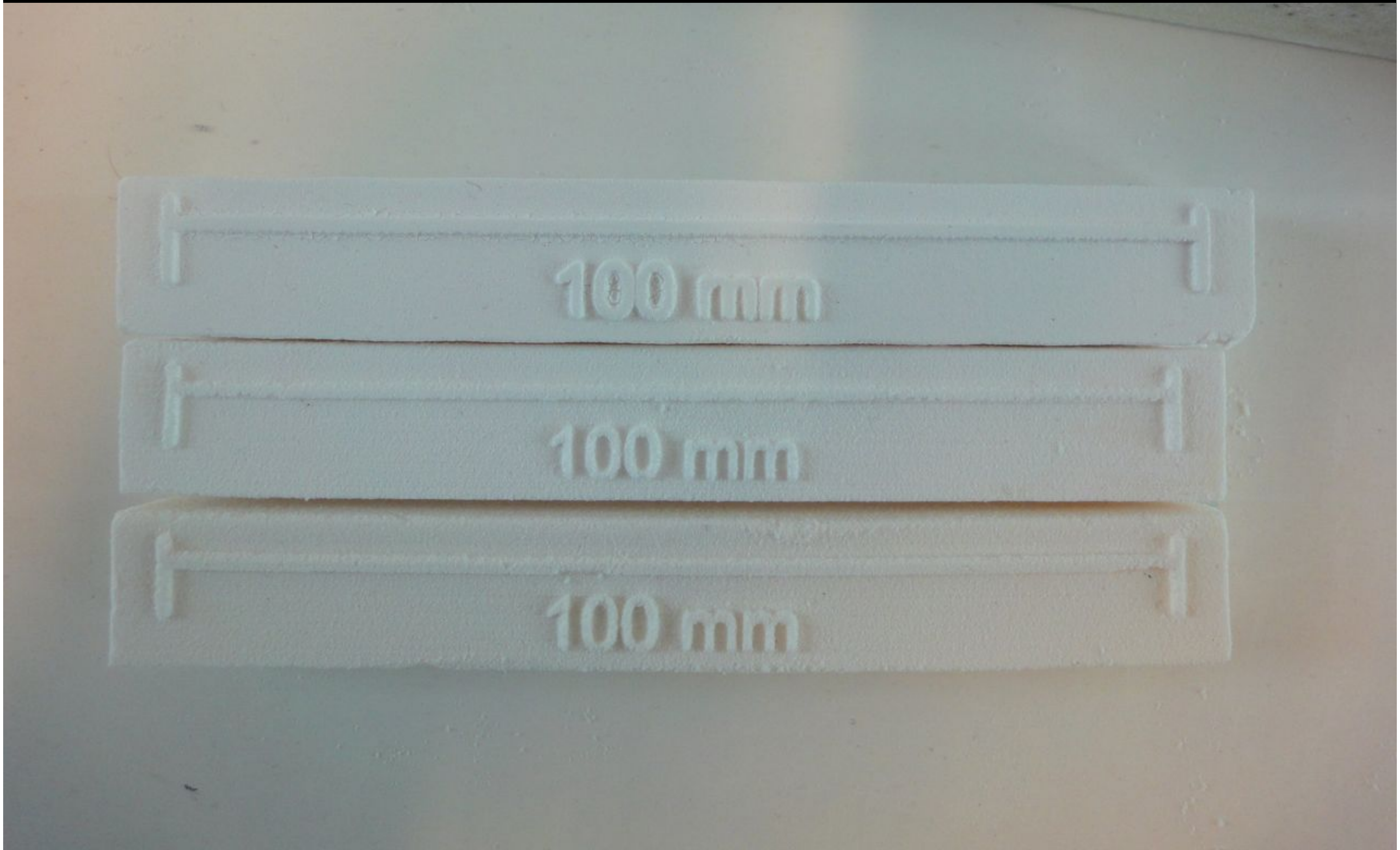
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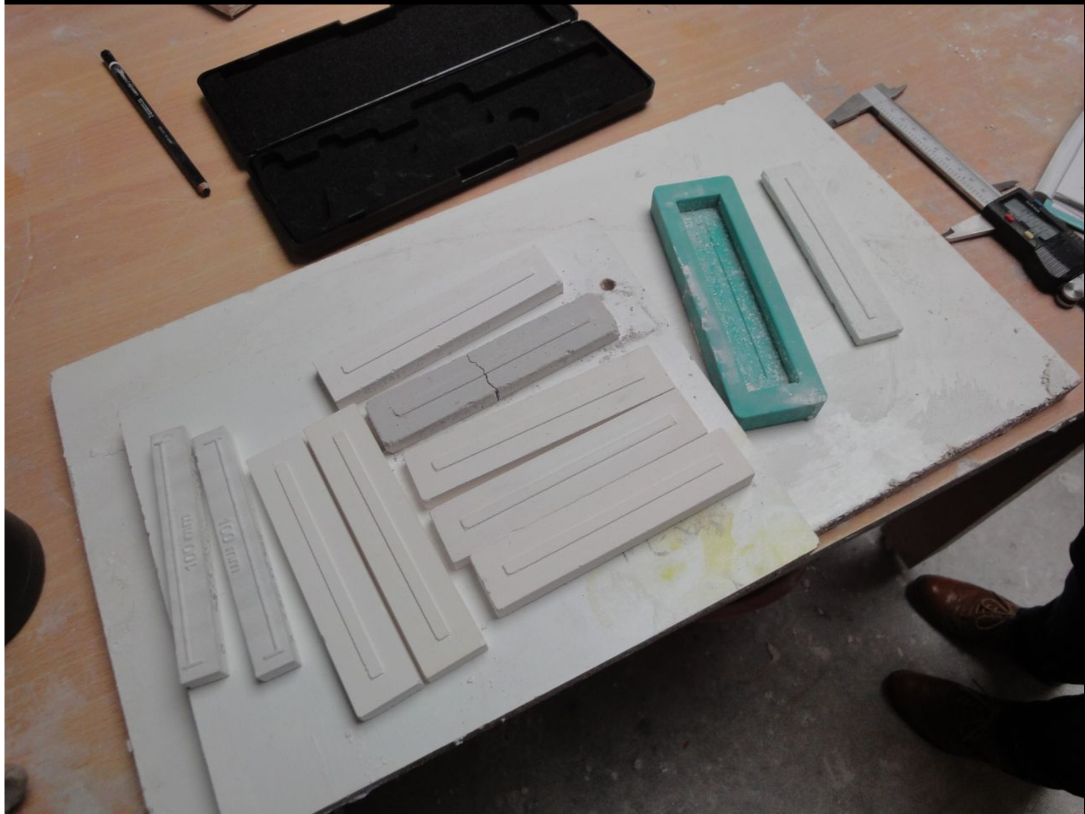


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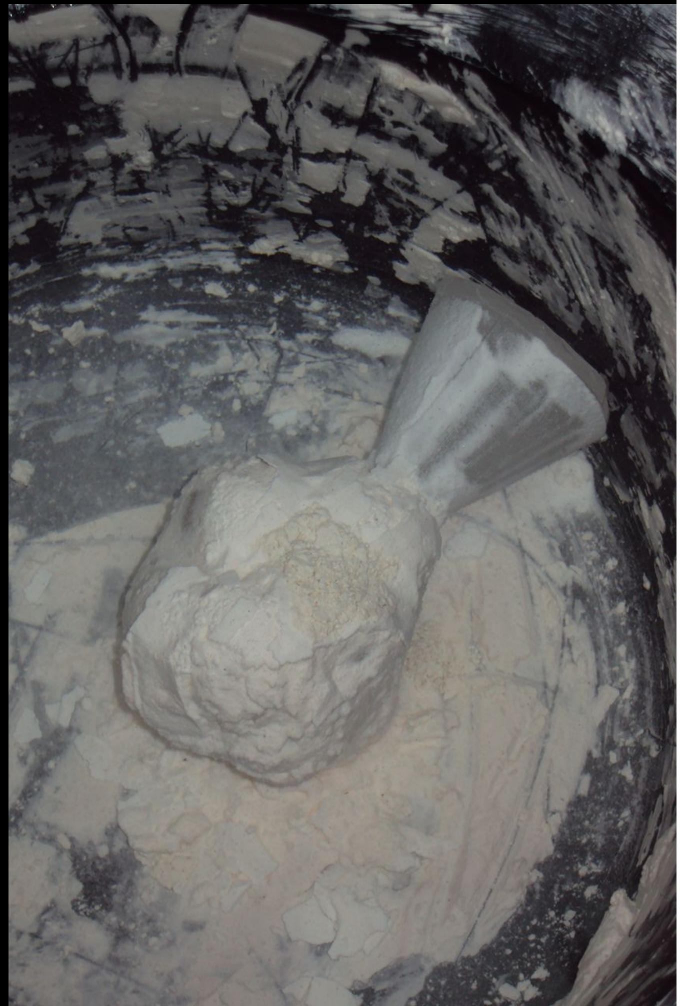


# Key points / advantages compared with conventional glass casting techniques:

- Very easy transition from CAD file to glass artefact
- New creative opportunities
- Lower firing temperature - allowing for the use of recycled glass
- De-moulding much easier
- Safer materials
- Potential for Better surface quality

# Key points / advantages

- Easy transition from Rapid Prototyping to Rapid Manufacturing

- Works with all current and new generation of ZCorp 3D printers - no need for retro fit or special material

- Works with standard building medium (zp150)

- Applications beyond glass

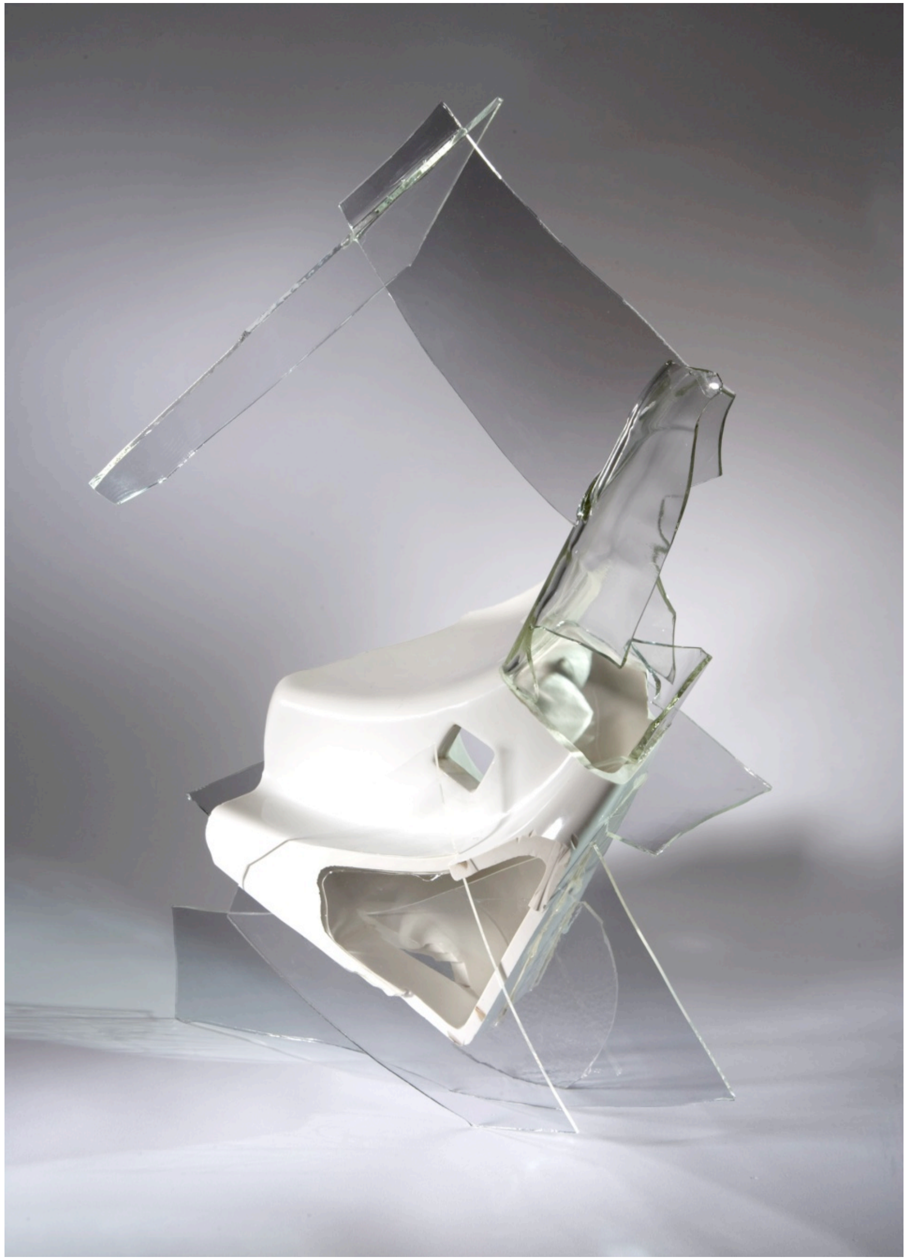
- Incredibly low cost


INSPECT FOR DAMAGE BEFORE ACCEPTING
DO NOT TOP LOAD
THIS END UP
FRAGILE


ZCORPORATION

Gayle Matthias

Research Application: combining ready-mades with digital printing



Anatomical Deconstruction
Series IV & I

Application of Research

Work within the restrictions of an exhibition deadline

Solve the dilemma of how to combine low tech construction methods with digital processes

Maintain a consistency of concept across a series

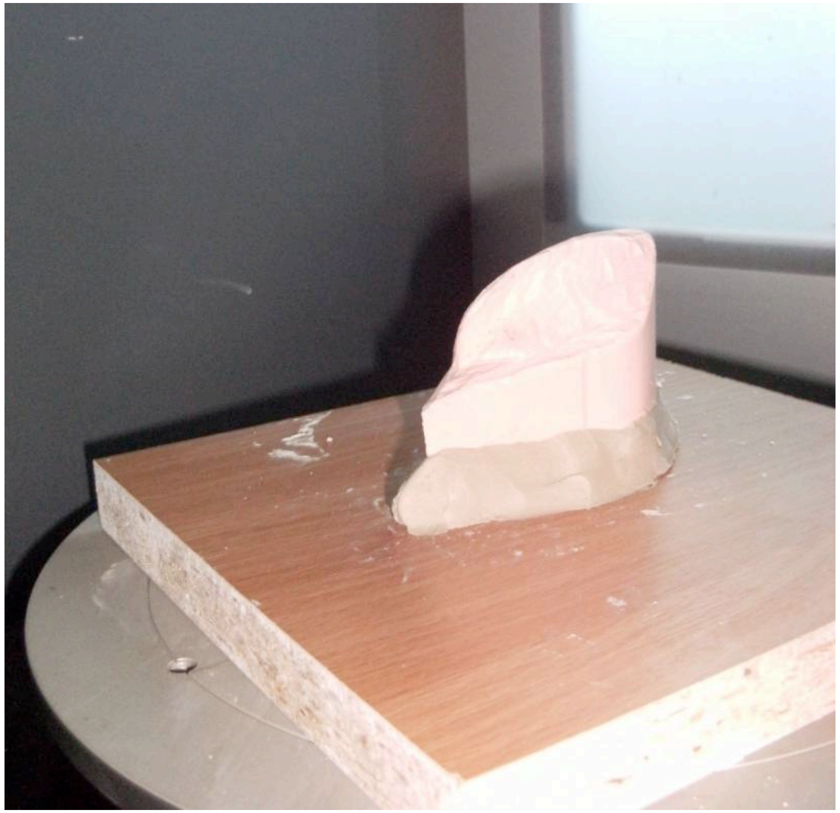
Extend my material language

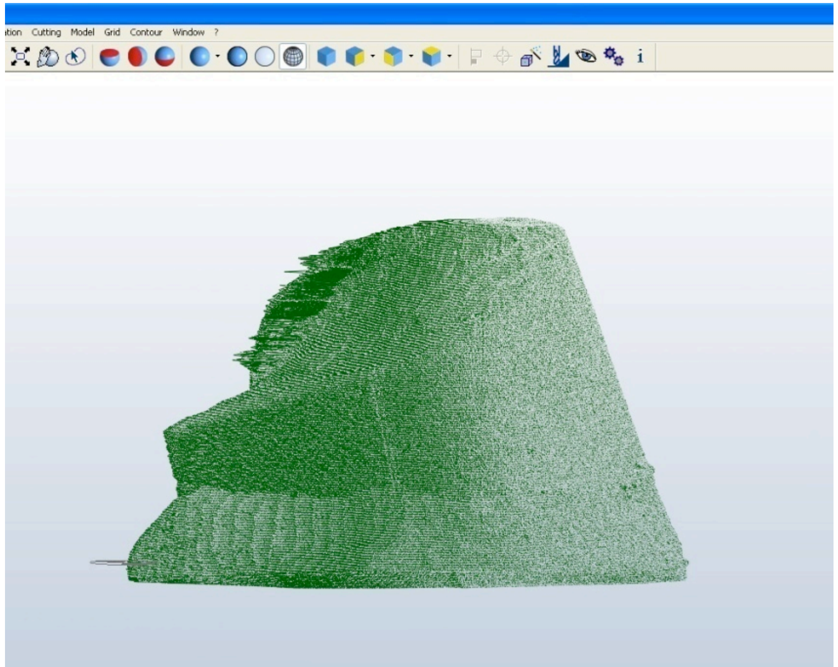

SUPERFLEX

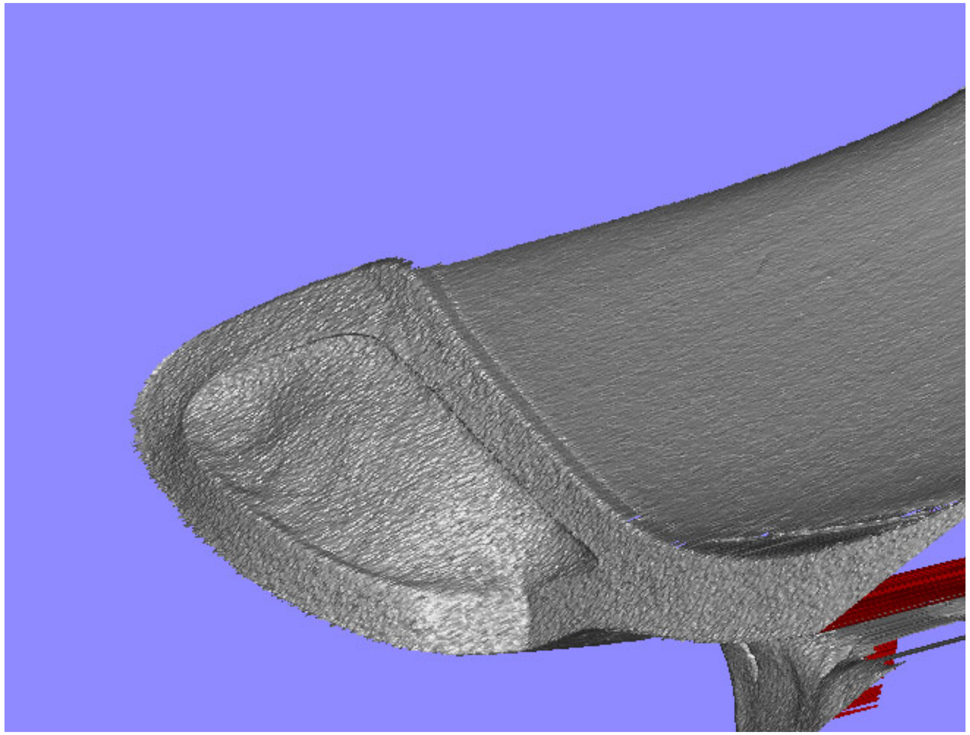


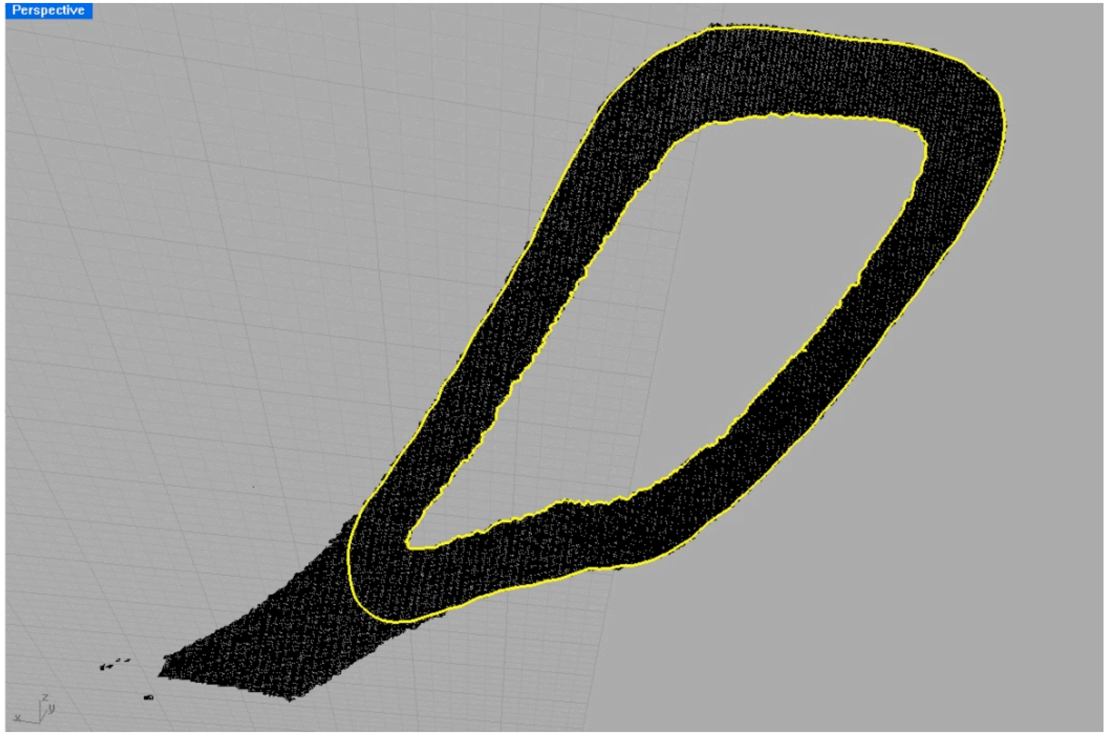


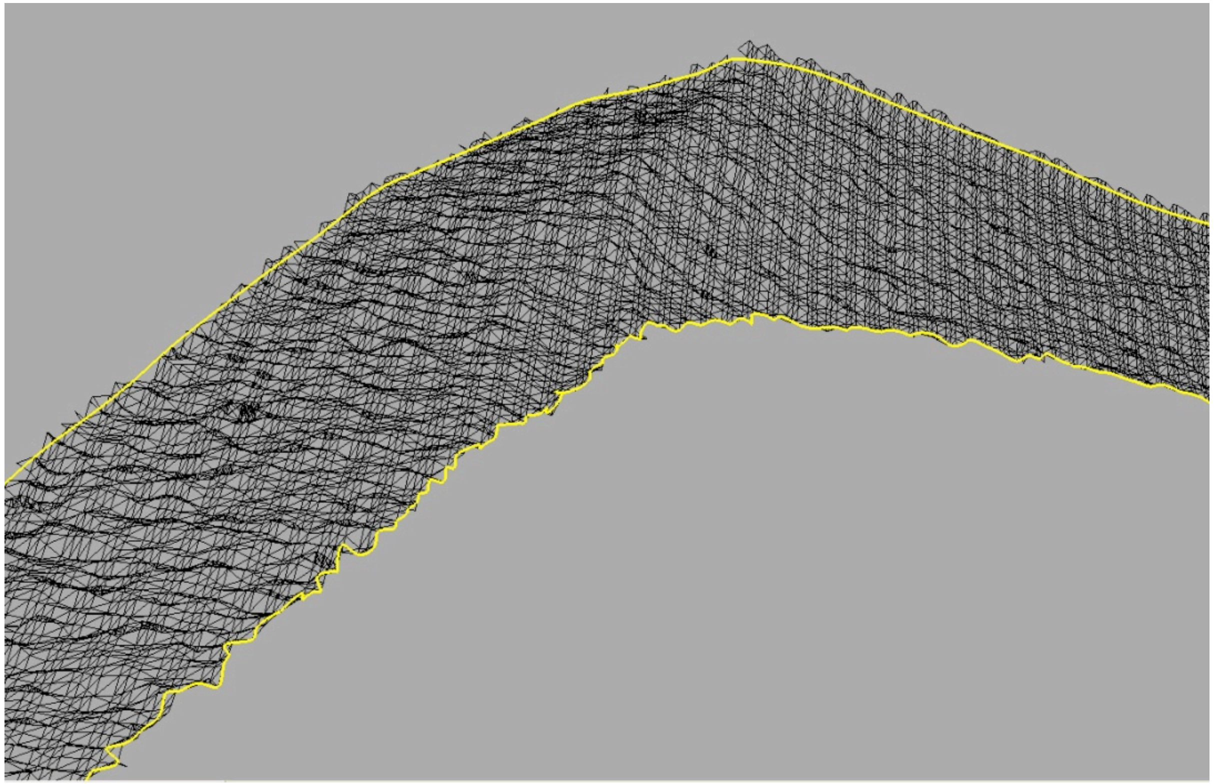

Roland
PICZA
3D LASER SCANNER

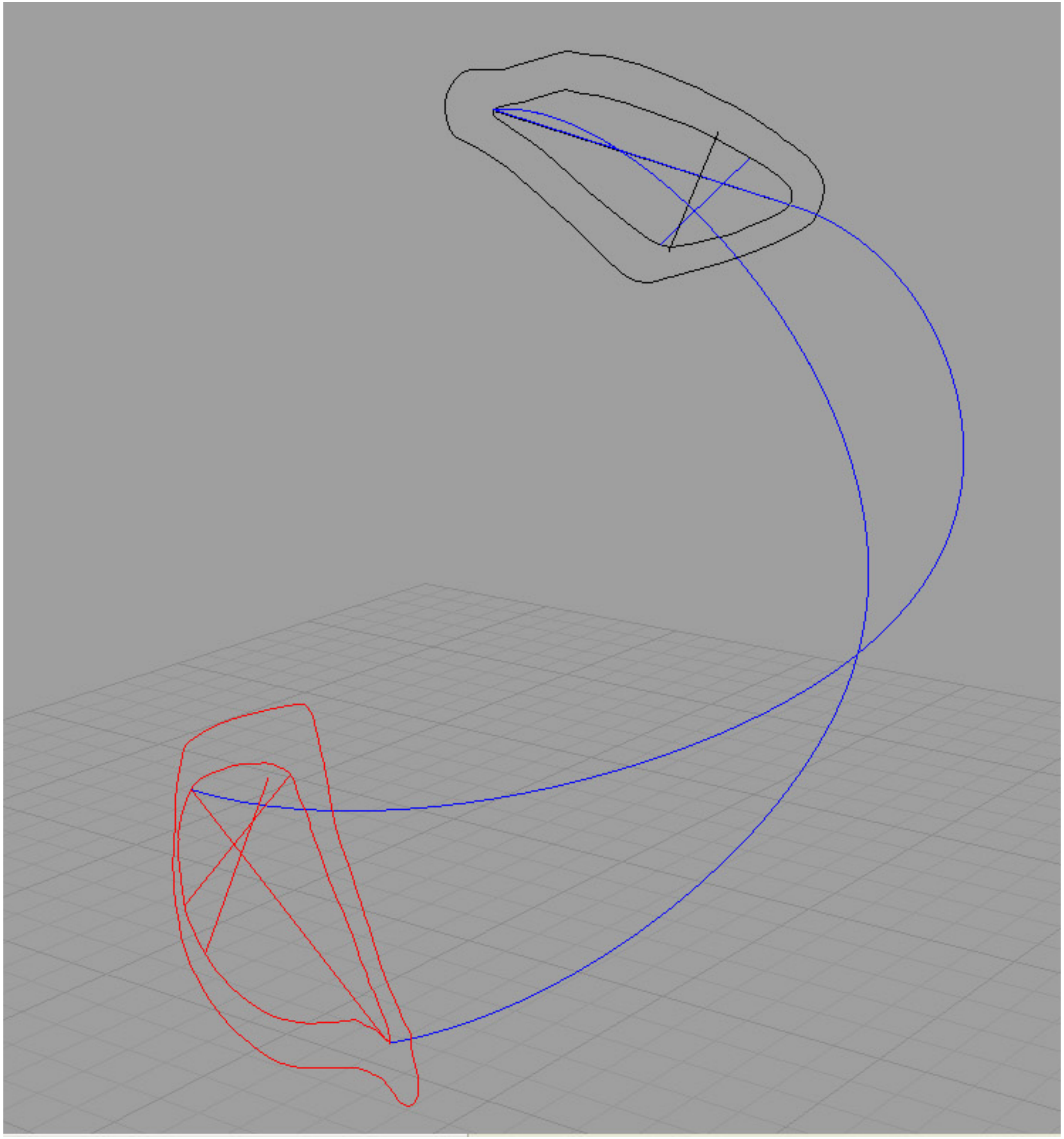


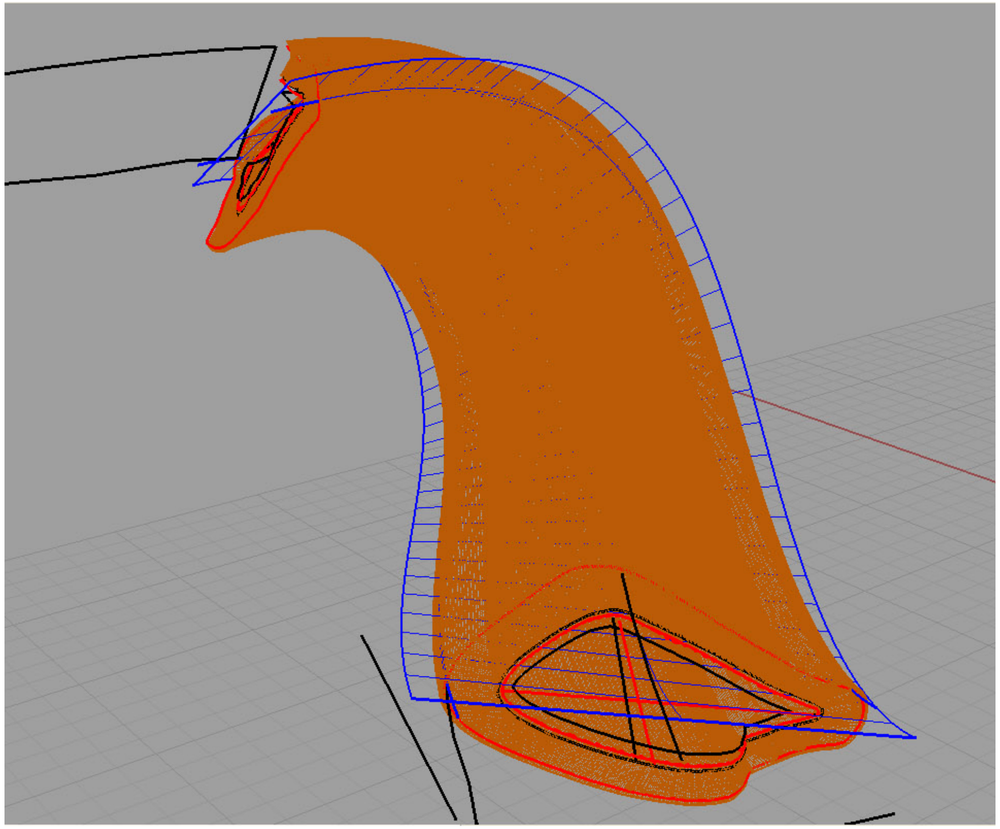
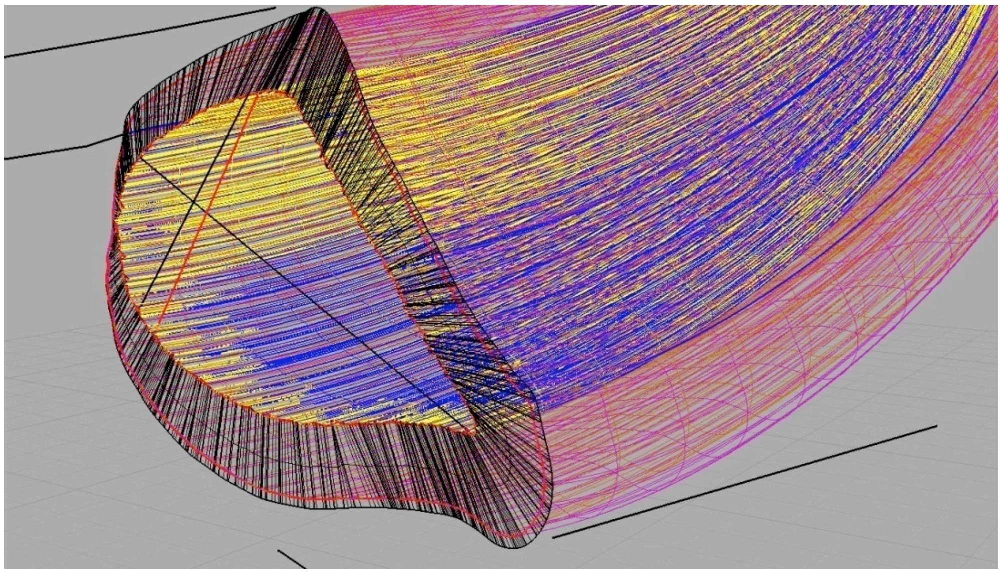
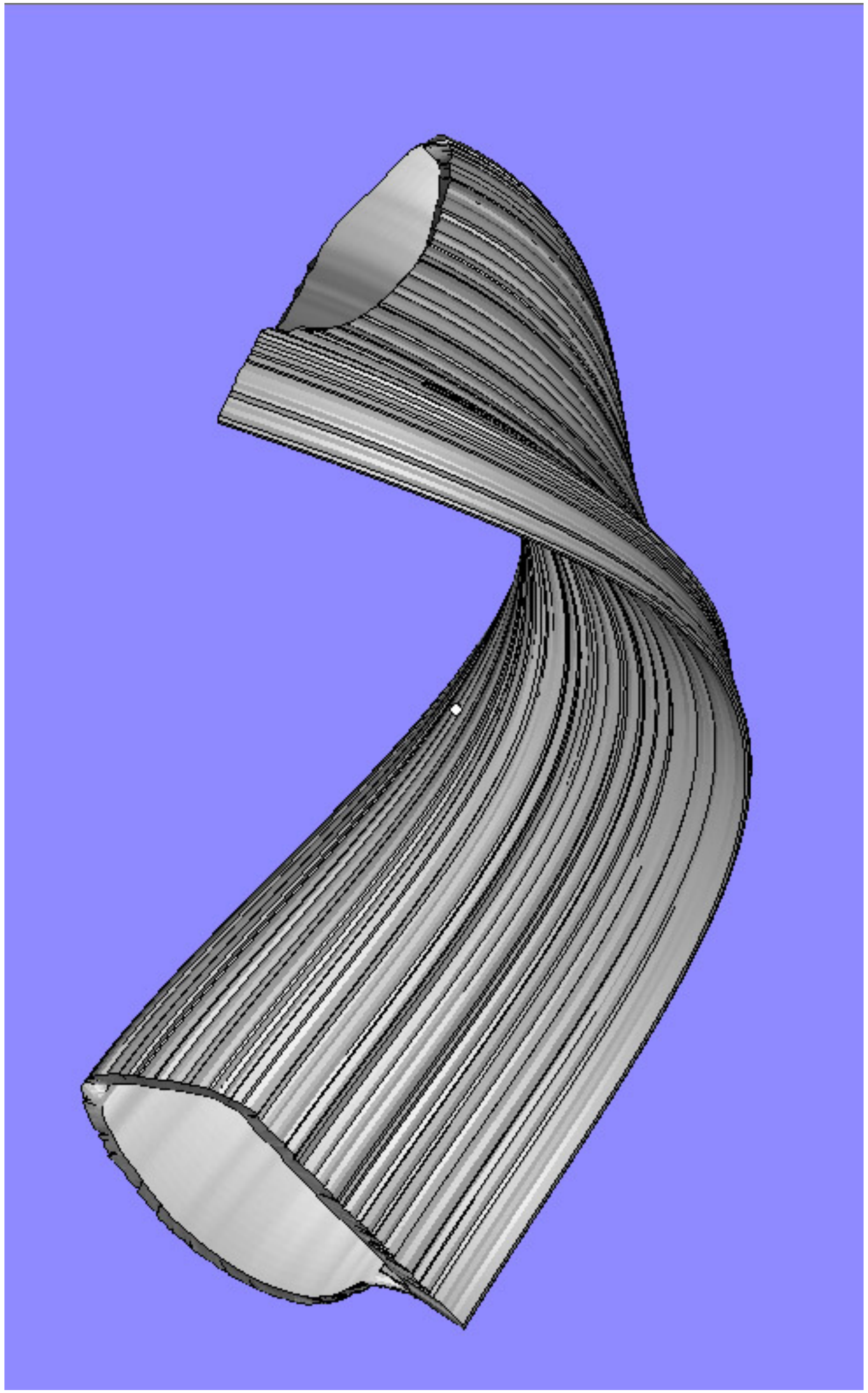

Cutting Model Grid Contour Window ?

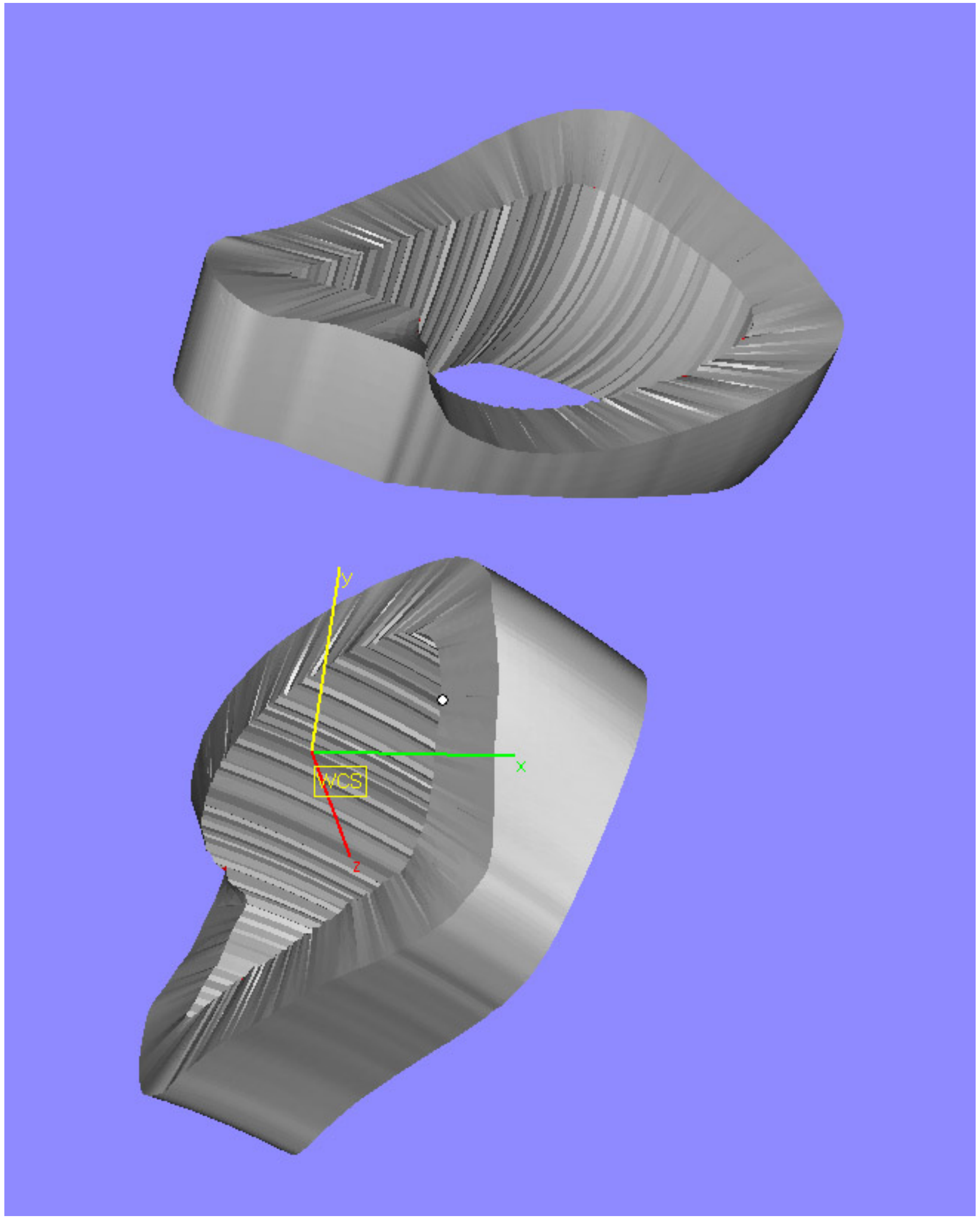



Perspective



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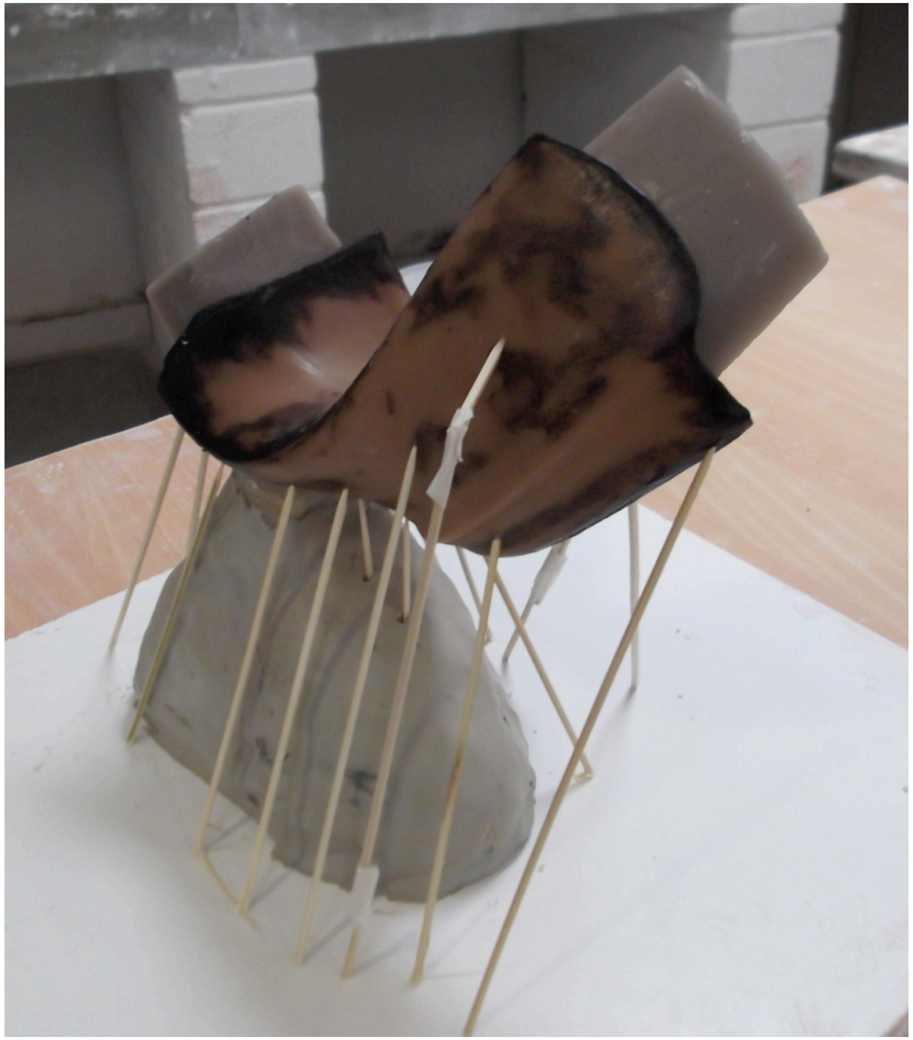

# Comparing traditional lost wax casting and digital RP moulding

| positive | → | negative | → | positive | → | negative | → | positive |
|---|---|---|---|---|---|---|---|---|
| Digital model | → | Rubber mould | → | Wax model | → | Refractory mould | → | Cast glass |
| Digital RP mould | → | Cast glass | | | | | | |




Melt exhibition at The Glass Gallery, London, November 2011

Sinew

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## Thank you to:

Emco

Zcorp

Gafferglass

Laserlines / Stratasys

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